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IMAGE ANALYSIS STUDY OF THE FEED, CONCENTRATE AND TAILS (AUGUST 1984) FROM THE CAROL LAKE CONCENTRATOR OF THE IRON ORE COMPANY OF CANADA

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by

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ABSTRACT

An image analysis study was performed on samples of feed, concentrate and tails obtained from the spirals circuit of the Iron Ore Company of Canada during the month of August, 1984 to provide an example of the type of results that would be obtained by such a study. The analyses of the concentrate showed that about 90% of the hematite and magnetite is in free grains that range from 70 to 1000 µm in diameter, the remaining 10% is in particles that contain 50 to 90 vol % hematite and magnetite as grains that range from 100 to 900 µm in diameter. About one-half of the quartz in the concentrate is in free grains that range from 70 to 600 µm in diameter. The analyses of the tails showed that about 88% of the iron in the tails is in hematite and magnetite and about 60% of this iron is in free grains. Most of the free grains are smaller than 150 µm in diameter with nearly half of them being smaller than 37 µm. The unliberated hematite and magnetite occurs as inclusions in quartz with most of the inclusions being 13 to 74 µm in diameter.

ÉTUDE PAR ANALYSE D'IMAGE DES ÉCHANTILLONS OBTENUS EN AOÛT 1984 AU MOYEN DU CONCENTRATEUR QUE POSSÈDE LA IRON ORE COMPANY OF CANADA À CAROL LAKE

par

W. Petruk

RÉSUMÉ

Une étude par analyse d'image portant sur des matières premières, un concentré et des résidus obtenus au cours du mois d'août 1984 au moyen du circuit à spirales de la Iron Ore Company of Canada, a été effectuée dans le but de démontrer, par des exemples, le genre de résultats qui peuvent ainsi être obtenus. L'analyse du concentré indique qu'environ 90 % de l'hématite et de la magnétite se retrouve dans les grains libres dont le diamètre varie entre 70 et 1000 µm, les 10 % restants se présentant sous forme de particules contenant de 50 à 90 % (vol.) d'hématite et de magnétite en grains, lesquels ont un diamètre variant entre 100 et 900 µm. Environ la moitié du quartz que renferme le concentré se retrouve sous forme de grains libres dont la granulométrie varie entre 70 et 600 µm. Une analyse des résidus indique que 88 % du fer qu'ils contiennent est présent sous forme d'hématite et de magnétite et qu'environ 60 % de ce fer se retrouve sous forme de grains libres. La plupart des grains libres ont un diamètre inférieur à 150 µm et environ la moitié ont une granulométrie inférieure à 37 µm. L'hématite et la magnétite non libérées se retrouve dans le quartz sous forme d'inclusions dont le diamètre varie de 13 à 74 um.

INTRODUCTION

Samples of SSU feed, BC 4+10 concentrate and CST tails obtained from the concentrator of the Iron Ore Company of Canada during August, 1984 were received at CANMET for an image analysis study. The purpose was to provide an example of the type of results that would be obtained by such a study. The particles in the samples received ranged from 10 to 1000 µm in diameter. When such a wide size range of particles is present, it is necessary to screen the samples before preparing polished sections. Eleven polished sections were prepared from each sample, and each polished section was analyzed separately to determine the mineral characteristics.

METHOD OF ANALYSIS

The minerals were identified by using the energy dispersive X-ray analyzer (EDXA) on the scanning electron microscope (SEM), and the mineral quantities and mineral liberations were determined with the image analysis system.

MINERAL IDENTITIES

It was found that the major minerals in the samples are hematite, magnetite and quartz; minor ones are carbonates; and trace minerals are goethite, apatite and biotite (Fig. 1, 2 and 3). Two varieties of carbonates were found. The most abundant carbonate mineral is a calcium-rich variety that contains some iron, magnesium and manganese. Sixteen grains of this carbonate were analysed semi-quantitatively with the EDXA and the equivalent CO_3 contents were calculated. The average composition of these grains in wt % is Ca 22.5, Fe 9.4, Mg 4.6, Mn 3.9 and CO_3 59.6 (Table 1). The second variety of carbonate is siderite and two types were found (Fig. 4); one is Fe-rich and the average composition for 4 grains, in wt % is Fe 38.6, Mn 2.9, Ca 1.24, Mg 3.1 and CO_3 54.2; the other type is Mn-rich containing about 10-12 wt % Mn and 25-29 wt % Fe.

MINERAL QUANTITIES

The quantities (in vol %) of major and minor minerals in each screened fraction were determined by analyzing with the image analyzer for the quantity of each mineral exposed in each polished section. The mineral pairs siderite and goethite, and hematite and magnetite were combined as a composite mineral for each pair because it was difficult to easily discriminate the two minerals. However, it is possible to discriminate the minerals if it is necessary to do so. The data were converted from vol % to wt % using the specific gravities of 2.65, 3.0, 3.8 and 5.2 for the quartz, carbonate, siderite-goethite and hematite-magnetite respectively (Table 2). The contribution of each mineral in each fraction to the mineral quantities in the total sample of SSU feed, BC 4+10 concentrate and CST tails were calculated by using the wt % of each screened fraction. The sum of the contribution from each fraction is equal to the quantity of mineral in each sample (Table 3).

LIBERATION CHARACTERISTICS OF THE HEMATITE-MAGNETITE

The liberation characteristics of the hematite-magnetite mineral pair were determined by measuring the percentages of hematite-magnetite that occur in each grain, and by classifying the grains as those that contain 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100% hematite-magnetite. The results are given in Table 4 and are plotted as histograms for hematite-magnetite in each screened fraction (Fig. 5, 6 and 7). The data for each screened fraction were combined into data for each sample by using the quantities of hematite-magnetite in each screened fraction and the wt % of each fraction in the sample to determine the classes of hematite-magnetite in each sample (Table 4 and Fig. 8). Grains containing 90-100% hematite are considered to be free grains, and the hematite-magnetite in the other grain classes are considered to be unliberated hematite-magnetite. The quantities of free hematite-magnetite in each screened fraction and in the samples are given in Table 5. The data are plotted in Fig. 9 to show the contribution of the free and unliberated hematite-magnetite from each screened fraction to each sample.

The size distributions of the unliberated hematite-magnetite grains in the screened fractions of the tails were determined by measuring the chord

lengths of the unliberated grains (Table 6 and Fig. 10). These size distributions show that most of the unliberated hematite-magnetite grains are smaller than 150 µm in diameter and suggest that it would not be realistic to liberate them by further grinding.

PERCENTAGES OF FREE QUARTZ IN THE CONCENTRATE

The percentages of quartz that are present as free grains in the screened fractions of the concentrate and in the combined sample of the concentrate are given in Table 7 and Fig. 11. The results show that about one-half of the quartz in the concentrate is present as free grains.

DISCUSSION

The iron contents of the SSU feed, the BC 4+10 concentrate and the SCT tails were calculated from the analyzed mineralogical composition of the screened fractions as 41.5, 66.3 and 15.4 wt % respectively by assuming that the carbonate contains an average 9.4 wt % iron, the siderite-goethite 40 wt % and the hematite-magnetite 70.7 wt %. The values correspond to 40.0, 66.8 and 17.3 reported by the company. The quartz content of the tails was analysed as 4.75 wt %, and the company reported 4.6%. The correlations are considered to be good and should provide confidence in the following values calculated from the image analysis data:

1. The percentages of iron in the feed, concentrate and tails due to hematite-magnetite are 97.3 (feed), 99.7 (concentrate) and 87.8 (tails).
2. The percentages of the hematite-magnetite that are present as free grains in the feed concentrate and tails are 72 (feed), 90 (concentrate) and 61 (tails).
3. Using the analyzed value of 15.4 wt % Fe for the tails, 8.2 wt % Fe in the tails is due to free hematite-magnetite and most of it is in particles that are smaller than 100 µm (Fig. 9). Similarly, 5.3 wt % Fe in the tails is due to unliberated hematite-magnetite grains that are largely 13 to 74 µm in diameter.

4. 59.7 wt % Fe in the concentrate is due to free hematite-magnetite and most of the free hematite-magnetite particles are 70 to 1000 μm in diameter (Fig. 9).
5. 6.5 wt % Fe in the concentrate is due to unliberated hematite-magnetite. Most is in particles that contain 50 to 90 vol % hematite-magnetite, and the particles vary from 70 to 1000 μm in diameter; the hematite-magnetite in these particles is 100 to 900 μm in diameter.

Table 1 - Semi-quantitative EDXA analyses for carbonate

	Grain No.	Ca	Fe	Mn	Mg	CO_3*
1	Carbonate	24	6	4	6	61
2	Carbonate	23	6	6	6	60
3	Carbonate	23	6	5	5	60
4	Carbonate	24	7	4	5	60
5	Carbonate	24	8	3	5	60
6	Carbonate	24	8	3	5	60
7	Carbonate	23	8	4	5	
8	Carbonate	22	9	7	5	59
9	Carbonate	23	9	4	5	60
10	Carbonate	24	10	2	4	60
11	Carbonate	22	11	3	5	59
12	Carbonate	22	11	4	4	59
13	Carbonate	22	11	3	4	59
14	Carbonate	21	14	4	3	58
15	Carbonate	20	14	4	3	58
16	Carbonate	21	15	2	4	
17	Mn-siderite	1	24	10	7	57
18	Mn-siderite	1	24	10	7	57
19	Mn-siderite		29	13	4	55
20	Siderite	1	35	4	5	55
21	Siderite		36	12		52
22	Siderite	1	39	3	3	54
23	Siderite	1	39	3	3	54

* calculated

Table 2 - Mineral quantities in screened fractions

Mineral	+20M	20-35M	35-48M	48-65M	65-100M	100-150M	150-200M	200-250M	250-325M	325-400M	-400M	Total Sample
Feed												
Quartz	54.1	15.8	27.1	45.5	58.8	50.9	34.5	29.9	21.0	15.3	11.4	33.7
Carbonate	5.8	2.0	10.2	11.2	7.5	8.5	8.6	6.1	8.8	7.5	8.2	8.5
Sil-Goe	0.5	0.1	4.5	0.4	0.5	0.5	1.2	1.0	0.1	0.5	0.4	0.6
Hem-Mag	61.6	82.1	58.1	39.9	53.2	54.5	55.9	67.0	70.1	77.1	80.0	57.2
wt % Fract	1.6	6.6	8.9	17.5	18.1	18.5	12.0	5.9	8.31	2.14	2.57	100.0
Cone												
Quartz	11.1	5.2	6.2	8.0	2.7	4.5	4.4	2.3	2.2	0.8	3.5	4.7
Carbonate	2.3	0.2	0.1	0.7	2.9	2.2	2.4	0.7	0.9	1.0	1.5	1.6
Sil-Goe					0.1		0.1	0.3	0.1	0.3	0.2	0.01
Hem-Mag	86.6	96.6	93.7	91.3	94.3	93.3	93.1	96.7	96.8	97.9	94.5	93.6
wt % Fract	1.84	8.27	9.29	18.16	19.65	20.56	13.3	2.65	5.55	0.33	0.44	100.00
Tails												
Quartz	72.2	59.4	89.8	70.6	78.1	77.5	60.8	51.7	33.6		20.1	63.2
Carbonate	6.4	25.0	28.7	20.6	12.7	15.1	15.1	17.1	16.1		13.4	17.1
Sil-Goe	0.5	0.3	0.7	0.6	0.4		1.2	1.5	1.6		1.1	0.6
Hem-Mag	20.9	15.3	10.8	8.2	8.8	7.4	22.9	29.7	48.7		65.4	19.1
Wt % Fract	2.12	5.84	6.96	15.41	13.75	22.47	10.7	10.18	5.01		7.56	100.00

* wt % calculated from vol % using assumed specific gravities.

Table 5 - Contribution of mineral quantities* by screened fractions to total sample

Mineral	+20M	20-35M	35-48M	48-65M	65-100M	100-150M	150-200M	200-250M	250-325M	325-400M	-400M	Total sample
Feed												
Quartz	0.56	1.07	2.42	8.57	7.02	6.84	4.1	0.99	1.78	0.33	0.29	33.7
Carbonate	0.06	0.14	0.91	1.93	1.35	1.54	1.03	0.24	0.74	0.16	0.21	8.5
Sid-goe		0.01	0.36	0.08	0.09	0.05	0.15	0.04	-	-	0.01	0.7
Hem-mag	0.98	5.56	5.25	6.89	9.61	10.1	6.68	2.59	5.83	1.65	2.06	57.2
Cone												
Quartz	0.21	0.26	0.58	1.45	0.53	0.93	0.59	0.06	0.12	0.003	0.2	4.75
Carbonate	0.04	0.02	0.01	0.12	0.58	0.46	0.32	0.02	0.05	0.003	0.007	1.63
Sid-goe					0.01	0.002	0.01	0.01	0.004	0.001	0.001	0.04
Hem-mag	1.59	7.99	8.7	16.54	18.53	19.17	12.38	2.54	5.36	0.33	0.42	93.6
Tails								200-270M	270-400M			
Quartz	1.53	3.47	4.16	10.83	10.74	17.41	6.54	5.26	1.68		1.52	63.1
Carbonate	0.14	1.46	2.0	3.17	1.75	3.39	1.62	1.74	0.81		1.02	17.1
Sid-goe	0.01	0.02	0.05	0.09	0.06		0.12	0.15	0.08		0.09	0.6
Hem-mag	0.44	0.88	0.75	1.27	1.2	1.67	2.45	3.03	2.44		4.93	19.07

* wt % calculated from vol % using assumed specific gravities.

Table 4 - Classification of heavy-magnetite

Class (vol % of fraction)	+20M	20-30M	30-40M	40-65M	65-100M	100-150M	150-200M	200-250M	250-325M	325-400M	-400M	Total sample
Coal												
0-10		0,5	0,8	4,8	1,1	1,0	1,8	1,2	0,4	0,1		1,4
10-20		0,4	0,7	5,4	1,3	1,2	0,8	1,4	0,5		0,1	1,4
20-30		0,6	0,7	1,5	1,9	1,9	1,7	5,0	0,7		0,6	1,5
30-40		1,8	2,4	3,2	1,4	1,4	3,6	10,4	1,6	0,3	0,4	2,5
40-50		1,1	0,5	4,5	5,9	5,7	3,5		2,6	2,6	0,3	3,5
50-60		0,9	1,1	7,2	5,4	7,0	5,1	5,6	4,4	1,6	1,7	4,6
60-70		2,9	0,2	3,4	6,2	5,0	4,2		5,4	1,7	2,8	3,8
70-80		2,3	2,2	7,3	4,4	5,4	5,6	2,2	4,9	0,3	3,2	4,4
80-90		5,9	1,4	6,0	4,1	0,9	3,1	4,5	6,9	1,3	2,7	3,5
90-100		84,6	90,0	56,7	67,1	70,3	70,6	69,7	72,6	92,1	88,2	71,71
Total		100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Gangue												
1-10	0,3	0,1	0,1	0,1	4,0	0,1	0,1	0,3		1,3	0,3	0,8
10-20	0,3	0,2	0,2	0,3	0,1	0,1		0,1			0,1	0,1
20-30	1,7	0,2	0,2	0,4	0,3	0,3	0,3	0,1			0,1	0,3
30-40	3,0	0,3	0,7	0,3	0,4	0,3	0,6	0,2			0,2	0,4
40-50	1,7	0,5	0,3	0,4	0,3	0,5	0,7	0,4	0,1		0,4	0,5
50-60	2,2	0,5	1,0	1,0	1,0	1,3	2,8	0,8	0,7	0,1	0,8	1,3
60-70	2,4	1,6	1,6	0,7	1,8	2,4	0,8	0,9		1,0	1,0	1,4
70-80	2,9	1,3	1,6	3,3	0,9	1,5	0,7	1,7	0,8	1,4	1,7	1,6
80-90	2,8	3,0	6,3	6,8	2,6	2,9	2,0	2,6	0,2	0,4	2,6	3,7
90-100	82,7	92,3	87,6	86,7	88,6	90,6	92,0	92,9	98,2	96,8	92,8	89,9
Total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Table 4 (Cont'd)

Class (vol % of hematite in grain)	+20M	20-35M	35-48M	48-65M	65-100M	100-150M	150-200M	200-250M	250-325M	325-400M	-400M	Total sample
Ratio								200-270M	270-400M			
0-10					19.3	18.6	3.2	1.7			0.1	
10-20					13.7	7.9	4.3	0.2			0.2	
20-30					11.7	2.5	4.3	3.6			0.8	
30-40					7.6	14.0	4.0	5.6			1.2	
40-50					7.6	1.6	9.9	4.3			1.0	
50-60					2.6	0.5	1.6	2.1			2.0	
60-70					2.2	1.6	4.1	1.4			0.4	
70-80					2.8	6.2	5.4	3.0			1.4	
80-90					2.6	1.8	3.2	2.7			1.2	
90-100					28.9	45.3	60.0	75.4			91.7	
Total					100.0	100.0	100.0	100.0			100.0	

* wt % of hematite-magnetite in each class of grain

Table 5 - Liberation of hematite-magnetite

	+20M	20-35M	35-48M	48-65M	65-100M	100-150M	150-200M	200-250M	250-325M	325-400M	-400M	Total sample
Feed												
Quant hem-mag	0.98	5.56	5.25	6.89	9.61	10.1	6.68	2.59	5.83	1.65	2.06	57.16
% of hem-mag free	3	84.6	90.0	56.7	67.1	70.3	70.6	69.7	72.6	92.1	88.2	71.7
Quant free	0.03	4.7	4.72	3.91	6.45	7.1	4.72	1.81	4.23	1.52	1.82	41.01
Quant unliberated	0.95	0.86	0.53	2.98	3.16	3.0	1.92	0.78	1.6	0.13	0.24	16.15
Conc												
Quant hem-mag	1.59	7.79	8.7	16.59	18.53	19.17	13.38	2.54	5.36	0.35	0.42	93.6
% free	82.7	92.3	87.6	86.7	88.6	90.6	92.0	92.9	98.2	96.2	92.8	89.8
Quant free	1.31	7.19	7.62	14.38	16.4	17.35	11.39	2.36	5.28	0.32	0.39	84.01
Quant unliberated	0.28	0.8	1.08	2.2	12.11	1.82	0.99	0.18	0.08	0.01	0.03	9.59
Tails								200-270M	270-400M			
Quant hem-mag	0.44	0.88	0.75	1.27	1.2	1.67	2.45	3.03	2.44		4.93	19.06
% free	0	0	0	10.0	28.9	45.3	60.0	75.4	85.1		91.7	60.08
Quant free	0	0	0	0.13	0.35	0.76	1.47	2.28	2.08		4.52	11.59
Quant unliberated	0.44	0.75	0.75	1.14	0.85	0.91	0.98	0.75	0.36		0.41	7.47

Table 6 - Unliberated hematite-magnetite

Size range (µm)	+20M	20-25M	35-48M
0-3.25	1.73	1.58	1.26
3.25-4.6	2.15	1.73	1.39
4.6-6.5	2.39	6.06	2.30
6.5-9.2	4.64	9.92	5.99
9.2-13	8.57	10.12	9.67
13-18.5	8.09	17.92	10.02
18.5-26	14.02	14.93	16.13
26-37	14.57	14.51	16.32
37-52	18.77	11.28	15.34
52-74	11.59	6.26	9.23
74-104	8.70	1.78	6.63
104-147	2.78	1.92	4.97
117-208	0.38	0.00	0.76
+208	1.02	0.00	0.00
Total	100.00	100.00	100.00

Table 7 - Per cent of quartz as free grains in concentrate

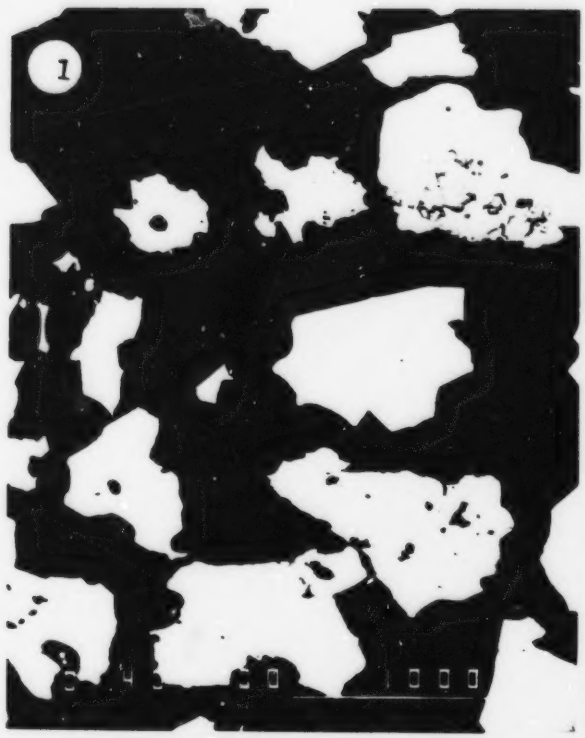
Screened fraction	Quant of quartz in fraction	% free	Quantity free
+20M	0.21	50	0.10
20-35M	0.26	50	0.13
35-48M	0.58	50	0.29
48-65M	1.45	80	1.16
65-100M	0.53	35	0.18
100-150M	0.93	49	0.45
150-200M	0.59	45	0.27
200-250M	0.06	41	0.02
250-325M	0.12	34	0.02
325-400M	0.003	23	-
-400M	0.02	57	0.01
Total sample	4.75	56	2.65

Fig. 1 - BSE-SEM photograph of 46-58 mesh fraction of the feed showing the hematite-magnetite grains (white), siderite and goethite (light grey) and quartz (dark grey).

Fig. 2 - BSE-SEM photograph of 48-65 fraction of concentrate showing hematite-magnetite grains (white), carbonate (grey), and quartz (dark grey).

Fig. 3 - BSE-SEM diagram of 48-65 mesh fraction of tails showing hematite-magnetite (white), carbonate (grey), quartz (dark grey), and a siderite grain in the centre (light grey).

Fig. 4 - High magnification of siderite grain in the centre of Fig. 3. The light grey areas are siderite, and the dark grey areas are Mn-siderite.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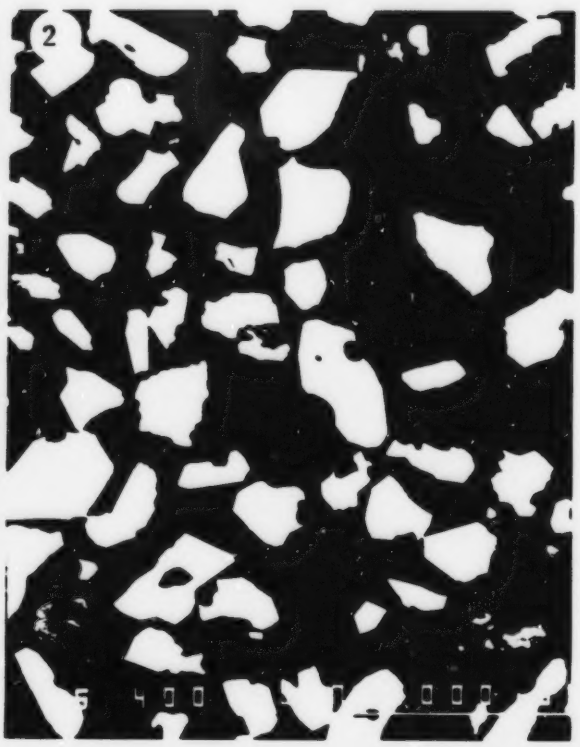
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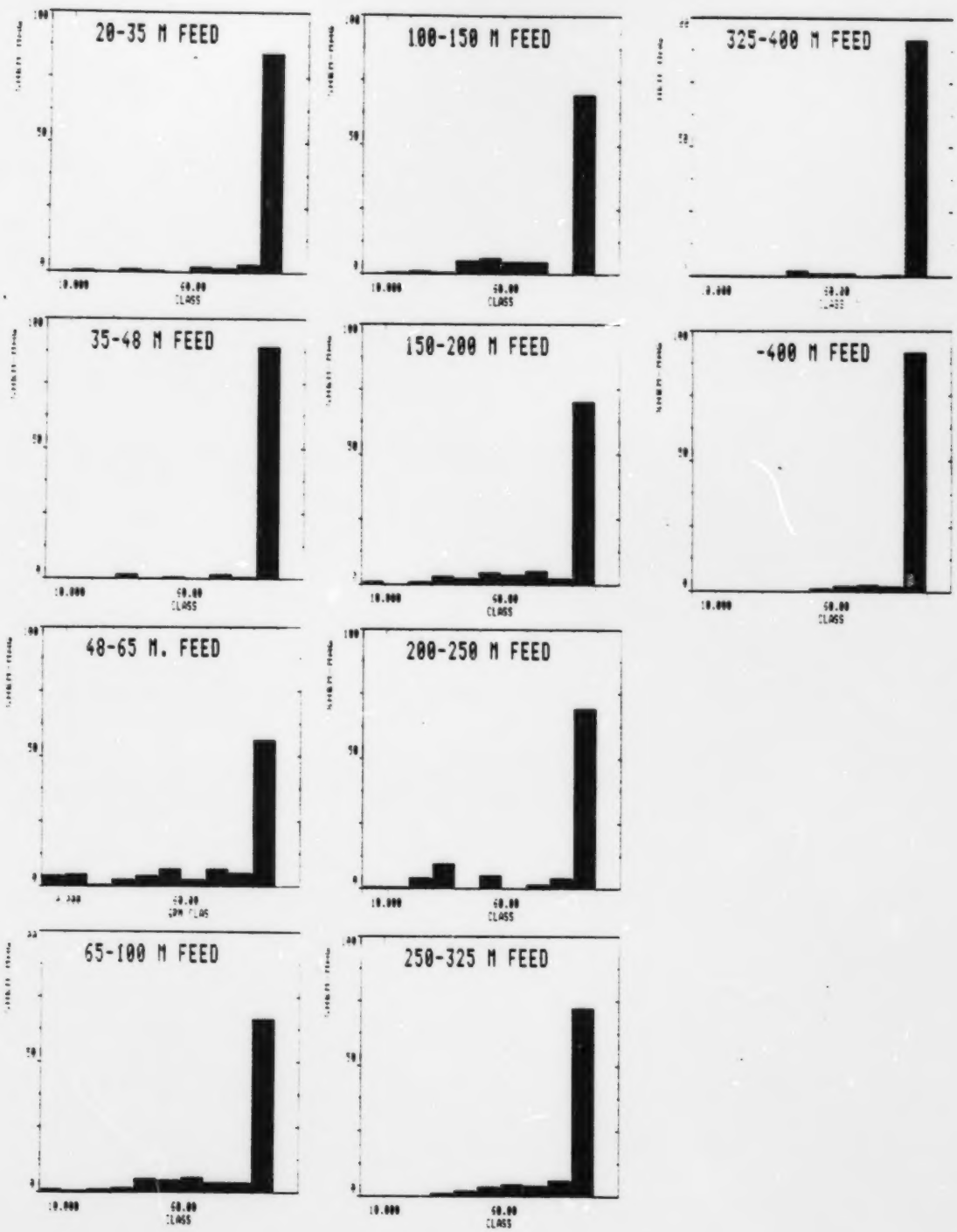

Fig. 5 - Histograms showing quantities of hematite-magnetite in particles from each screened fraction of the SSU feed.

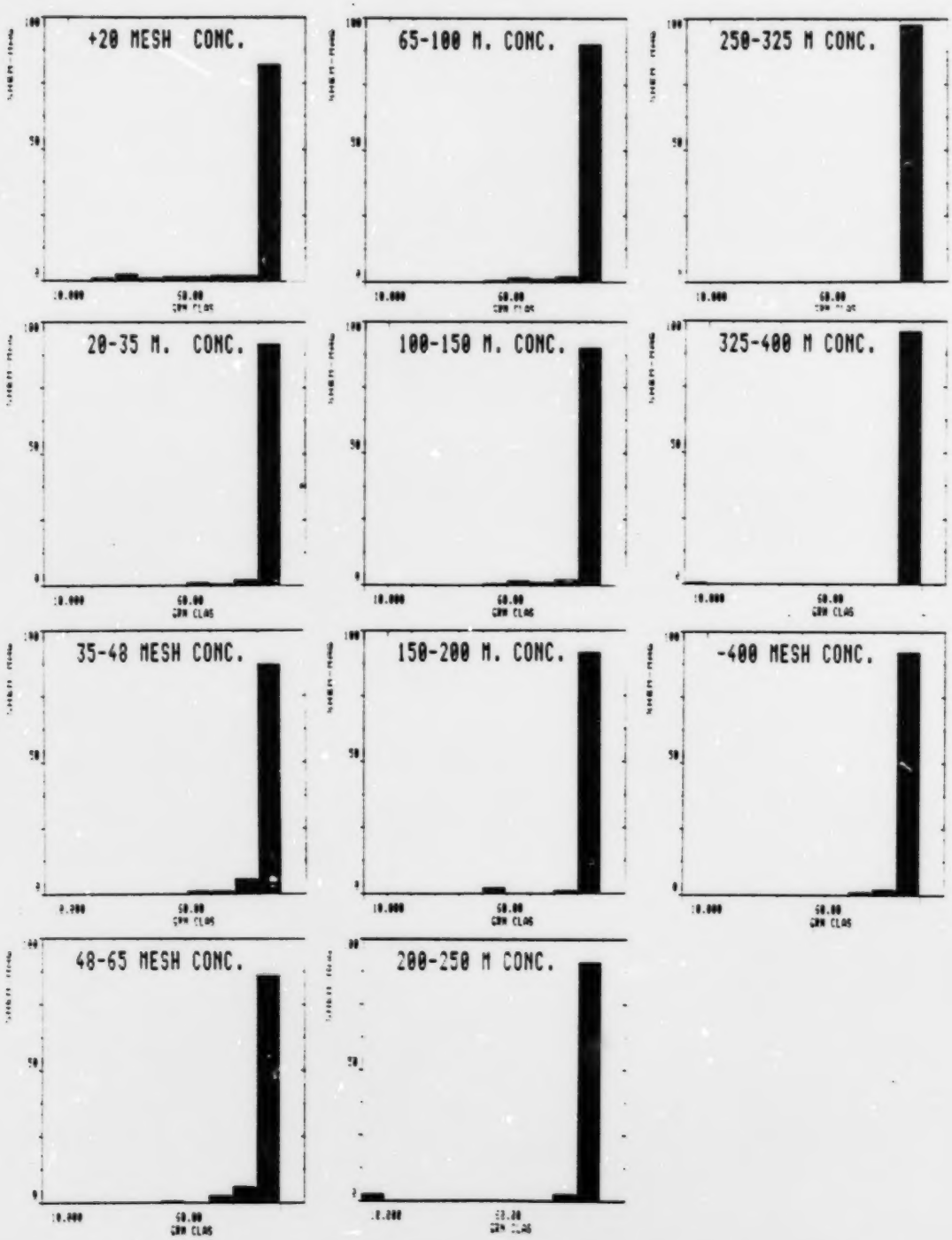

Fig. 6 - Histograms showing quantities of hematite-magnetite in particles from each screened fraction of the BC 4+10 concentrate.

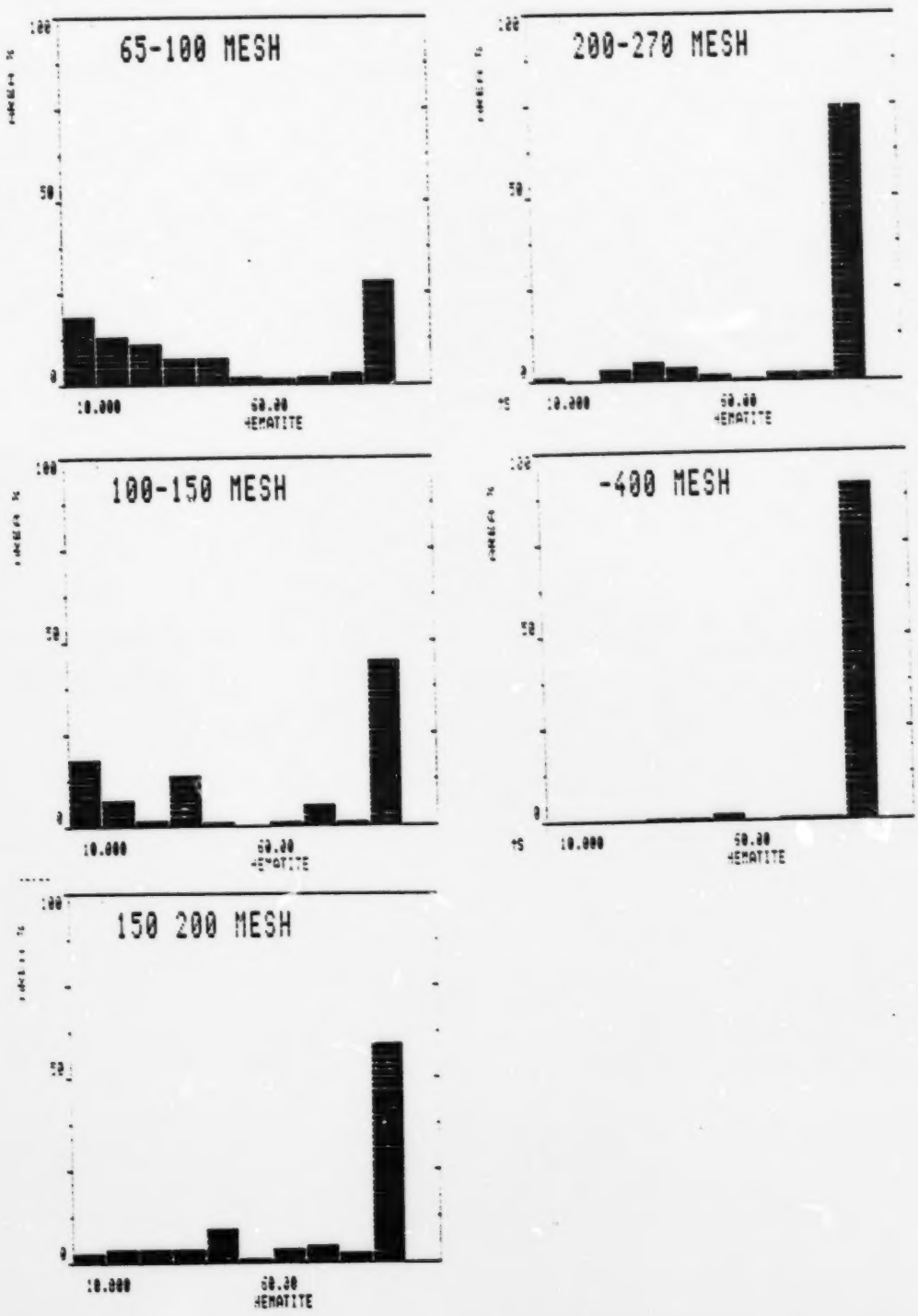

Fig. 7 - Histograms showing the quantities of hematite-magnetite in particles from screened fractions of the SST tails sample.

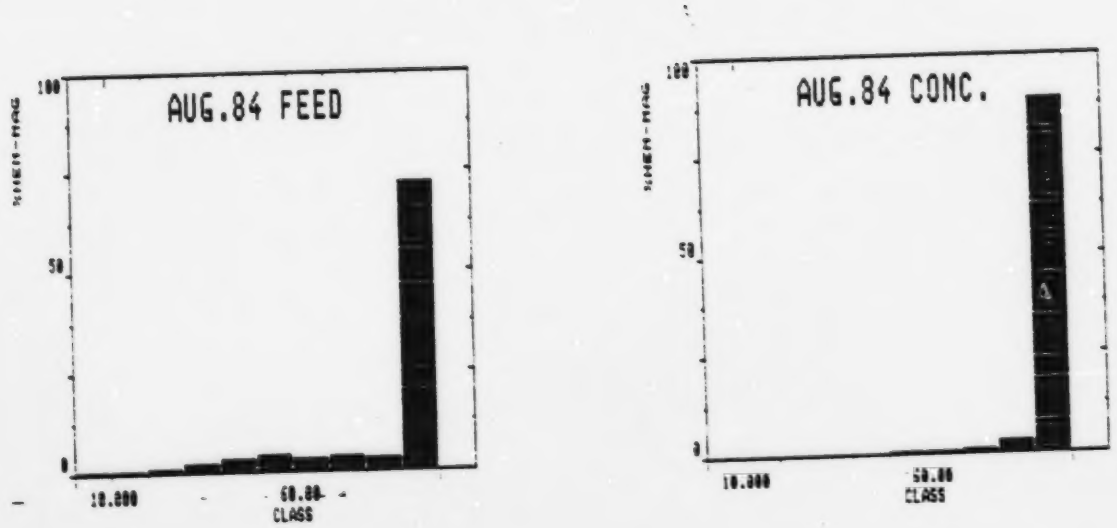

Fig. 8 - Summary histogram showing quantities of hematite-magnetite in particles in the SSU feed and BC 4+10 concentrate.

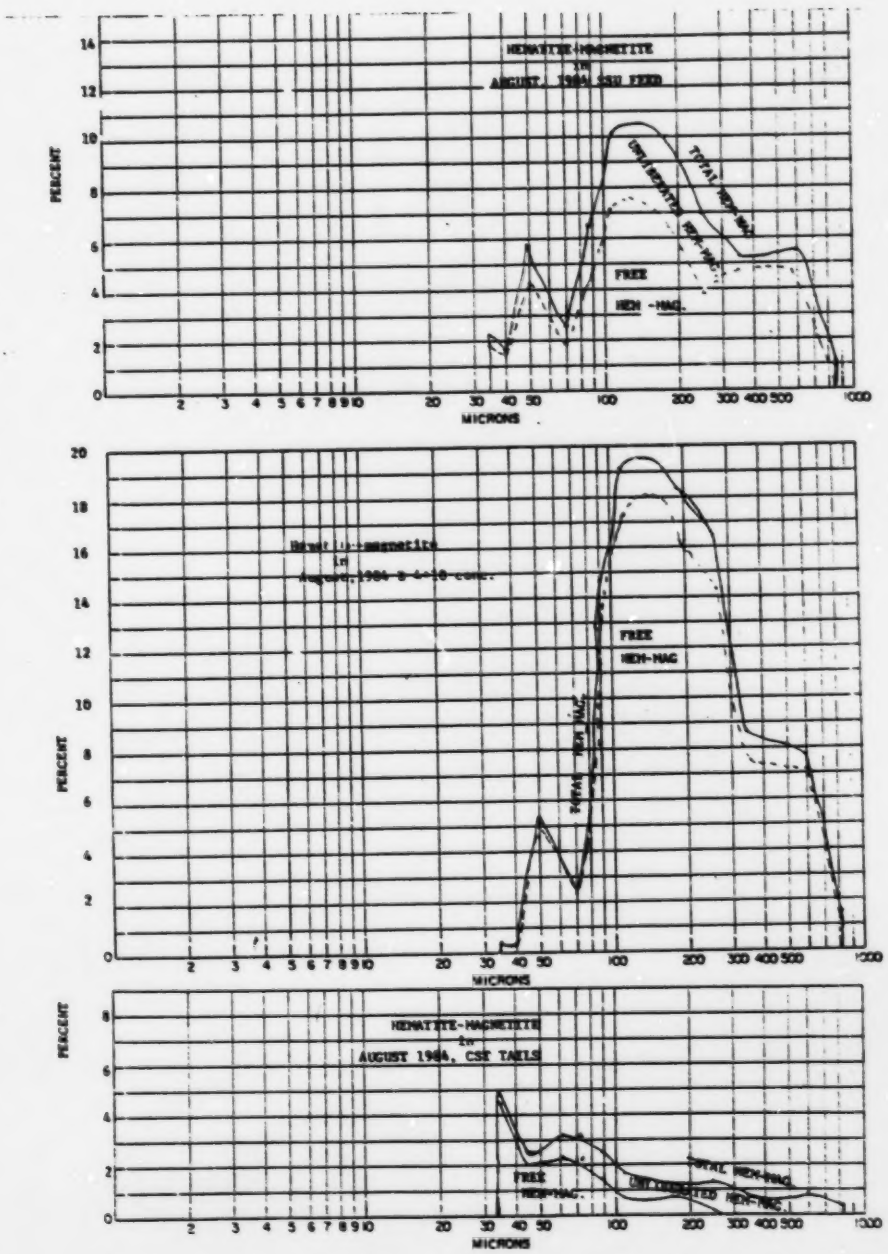

Fig. 9 - Diagrams for feed, concentrate and tails showing relative quantities of hematite-magnetite in grains of each size range (area under top curves), of free hematite-magnetite grains (area under bottom curves), and of unliberated hematite-magnetite (area between curves). The humps appear in the curves because the samples were not screened into fractions of equal Tyler size intervals.

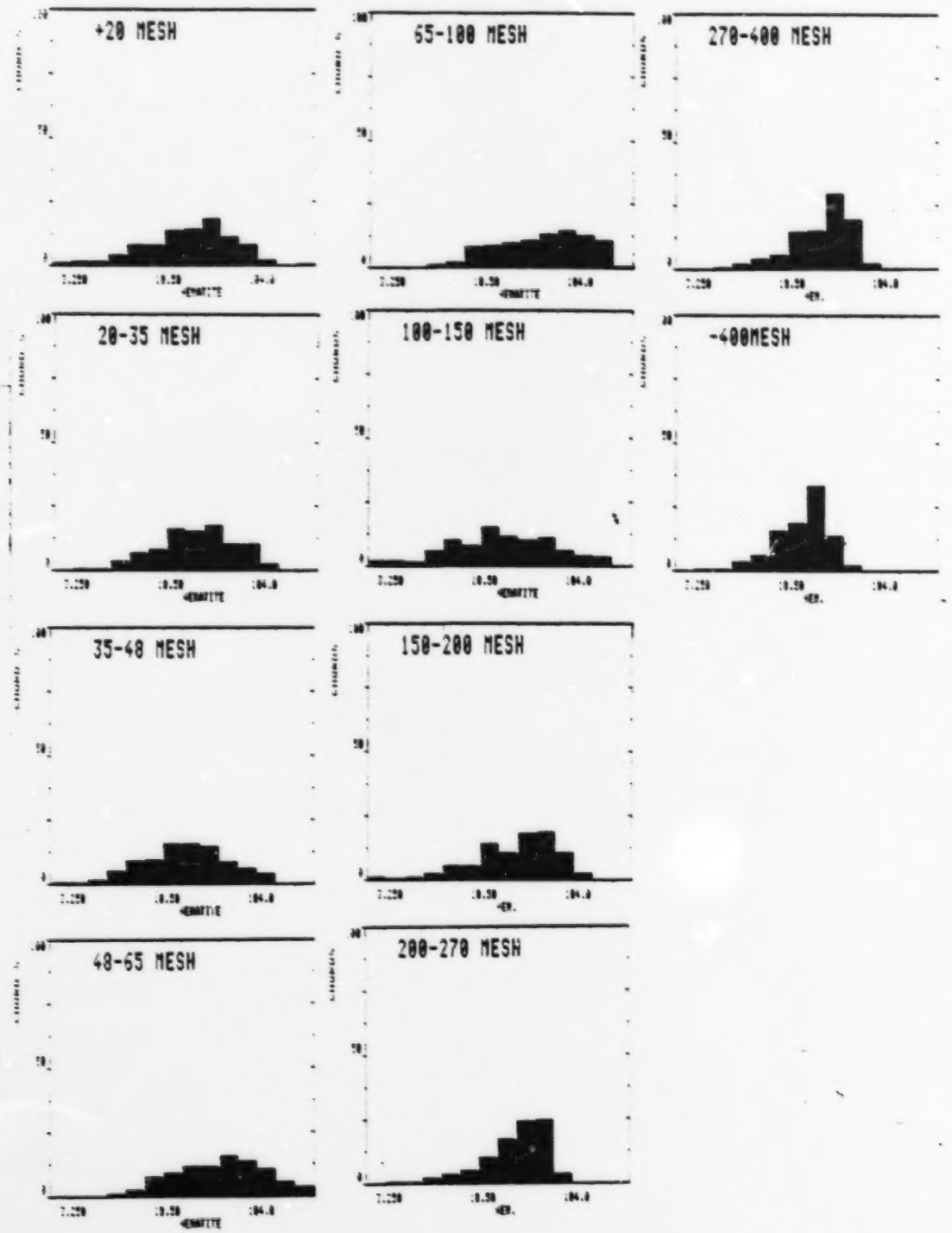

Fig. 10 - Size distributions of unliberated hematite-magnetite in screened fractions, determined by measuring chord lengths of unliberated grains.

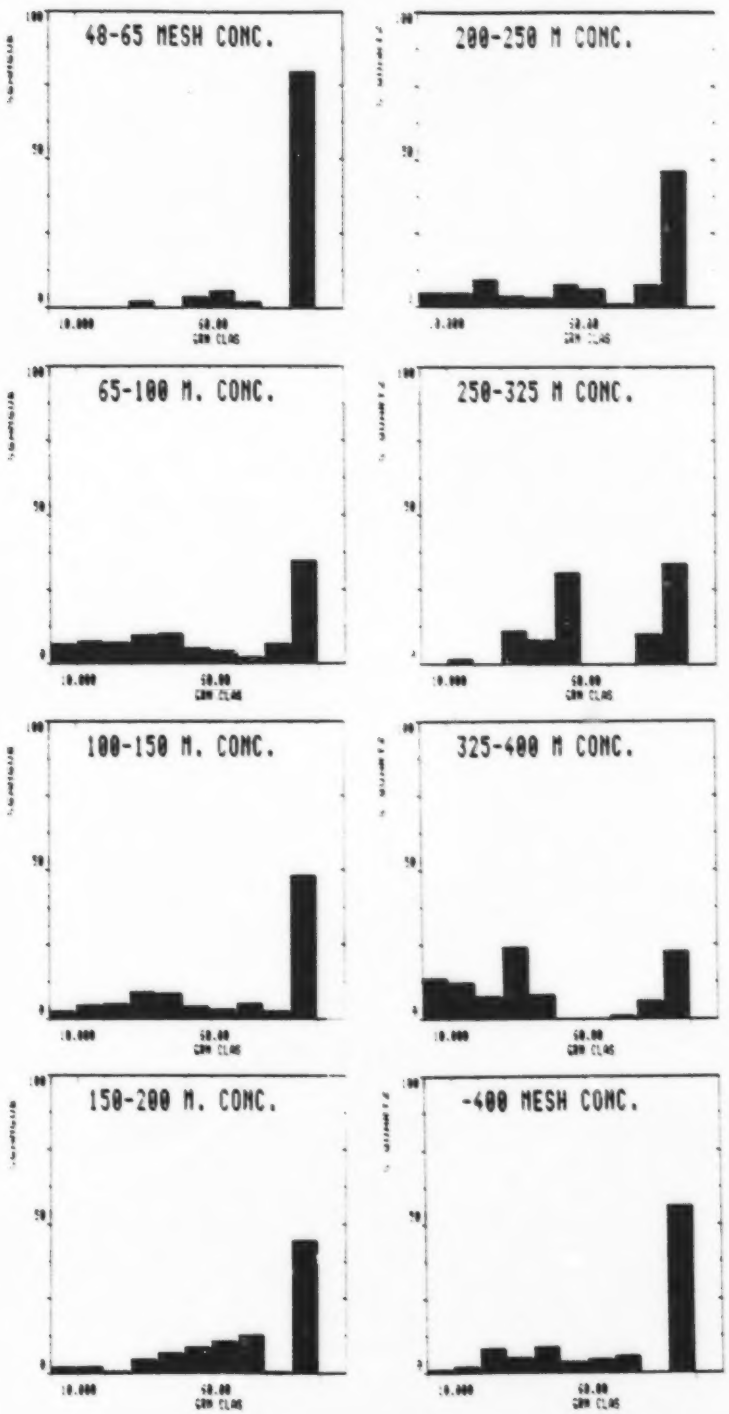

Fig. 11 - Histograms showing quantities of quartz in particles from each screened fraction of the BC 4+10 concentrate.

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